Not for publication

A MICRO-RECORDER FOR MEASURING SKIN TEMPERATURE AND SWEATING IN AIRPLANE PILOTS

by

WALTER R. MILES

A report of apparatus development and preliminary research conducted at Yale University School of Medicine, New Haven, Connecticut, by means of a grant-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots from funds provided by the Civil Aeronautics Administration.

December 1943

CIVIL AERONAUTICS ADMINISTRATION
DIVISION OF RESEARCH
REPORT NO. 24
WASHINGTON, D. C.

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National Research Council

Committee on Selection and Training of Aircraft Pilots

Executive Subcommittee

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National Research Council

1943

LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Selection and Training of Aircraft Pilots

December 11, 1943

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Washington, D. C.

Dear Dr. Brimhall:

Attached is a report entitled A Micro-Recorder for Measuring Skin Temperature and Sweating in Airplane Pilots, by Walter R. Miles. The report is submitted by the Committee on Selection and Training of Aircraft Pilots with the recommendation that it be included in the series of technical reports issued by the Division of Research, Civil Aeronautics Administration.

This report describes the development of a practical micro-recorder for measuring skin temperature and sweating. The improvements and advantages of this instrument over existing micro-recorders are described along with some results of its use in a preliminary experiment with student pilots. The primary value of the report is in the description of a development in instrumentation for future research in the measurement of "tension."

Cordially yours,

Morris S. Viteles, Chairman
Committee on Selection and
Training of Aircraft Pilots
National Research Council

MSV:rm

AUTHOR'S FOREWORD

In early discussions of the Committee on Selection and Training of Aircraft Pilots interest was expressed in the measurement of stress and tension in men who are being taught to fly. The assumption was that some degree of stress would be typical of beginners at the time of their early flights. Those showing exaggerated responses of this character and continuing to do so might prove temperamentally unsuited for flying.

A large variety of techniques and instruments for measuring degrees of stress have been proposed by physiologists and psychologists. Various aspects of the circulatory and respiratory functions have been used. Muscular and glandular reflexes, voluntary and involuntary movements, skin temperature and sweating, mental associations and judgments, verbal responses, and numerous other functions have been made the basis of attempts to measure the effects of emotional changes. The instruments devised have usually been for laboratory use, under conditions of relative quiet and freedom from movement on the part of the subjects. In most instances instruments for measuring emotional responses are rather complicated and cumbersome.

When considering the feasibility of using available laboratory instruments in training planes, many difficulties presented themselves. Weight and space requirements were critical. The student pilot must be allowed adequate freedom of motion to perform his work and safety must be assured. The author at this juncture recalled having seen a preliminary demonstration of a micro-climate recorder devised by Professor August Krogh of Copenhagen for measuring the body temperature underneath the clothing. The instrument was built on the chassis of a wrist watch and was self-contained, requiring no outside connections or accessory equipment. The micro-climate recorder not only qualified in reference to weight and space but seemed eminently well suited for application to a student pilot without offering interference with his movements or duties and presented minimal stimulus for distraction. Furthermore, no assistant need give attention to this instrument during the period of recording while in the plane. It was suggested that the author endeavor to secure such instruments from Professor Krogh. After several months, one of the units was procured. Conditions arising from the war made further procurement from Copenhagen impossible: If micro-recorders were to be used in the United States they would have to be built here.

This report embodies a discussion of the development of a modified micro-recorder and presents some preliminary results of its application. While these results are not definitive in character, they are sufficiently revealing to indicate the possible application of this instrument.

The development of a practical micro-recorder for measuring skin temperature and sweating in airplane pilots is a distinct contribution to the instrumentation in this field and this instrument will prove of considerable value in future research concerned with "tension."

CONTENTS

SUMMARY

1. Most of the large variety of laboratory techniques and instruments for measuring emotional responses are not directly applicable for use on student pilots while learning to fly. A small instrument known as the Krogh Micro-Climate Recorder at first seemed to have possibilities for such use. The Krogh recorder was, however, designed to be worn underneath the clothing. Features of its design proved not the most appropriate when the recorder was mounted on the hand near the palmar surface.

2. A newly designed instrument, the C.A.A.-N.R.C. Micro-Recorder, was constructed particularly for use on exposed areas of the skin. This new recorder makes use of some of the principles involved in the Krogh instrument. A small watch movement is employed to drive a recording disc capable of taking records over a period of twelve hours. A temperature unit and a humidity unit with small writing levers are mounted on the inside of the instrument at a position as close as possible to the front. By means of appropriate openings in the front plate of the watch case, the sensitive elements are directly exposed to the temperature and humidity 1 cm. from the skin, while the entire unit is mounted on a ring of porous rubber sponge material.

3. The details for the construction of the C.A.A.-N.R.C. Micro-Recorder, its calibration and the technique of reading the records are described and discussed in this report.

4. Preliminary tests were made on a group of Yale University students participating in the local Civilian Pilot Training program, and a few private students who were in process of training at a flying school near New Haven, Connecticut. This school was a favorable one for such tests, with the noteworthy exception that the single instructor felt unable to cooperate by making ratings on the students for tension and emotional stress during the periods of flight. This unfortunate circumstance limits the interpretations that might have been possible from the records secured.

5. A group of 20 illustrative records are reproduced, together with the pertinent data secured in connection with them and read from these records.

6. The data, representing the first trials for each of ten men, are grouped in separate tables for temperature and humidity, and described in reference to individual differences and to average tendencies. Other tabular groupings of data for individual students are presented and the averages discussed.

7. The records taken in these preliminary experiments show appreciable changes in temperature and in humidity associated with the experience of flight. In general the humidity and the temperature during flight are found to exceed the values registered before flight. The levels for humidity and temperature during flight tend to be prolonged into post-flight period, during which the instructor was talking with the student and writing out the report on his lesson.

8. Records for three first solo flights indicate quite high humidity and temperature during the flight and continued after the flight.

9. From the preliminary tests made, the C.A.A.-N.R.C. Micro-Recorder appears to qualify as a self-contained instrument applicable to flight students, and sensitive to their physical and mental conditions during these experiences. Its possible usefulness depends largely on the degree of cooperation that can be secured from the instructor, and upon the design and control of the test experiment.

A MICRO-RECORDER FOR MEASURING SKIN TEMPERATURE AND SWEATING IN AIRPLANE PILOTS

PART I

Micro-Recorders and Technique of Use

The Krogh Micro-Climate Recorder

Krogh, in describing his recorder unit, says: "The immediate problem for which the recorder here described was constructed was the study of the temperature and humidity relations inside the clothes of man, but it is felt that it may have a wider range of usefulness, and this is the reason why it is published before anything definite has been achieved by means of it."[1] Earlier small recorder units have been devised for use in meteorological studies. They were of such size as could be sent up attached to a pilot balloon. The records were made on smoked glass, and were read under a microscope. Using a fairly large sized watch as motive power, Weichmann, in 1938, devised a recorder which included a bimetal thermometer and a hair hygrometer.[2] The hands of the watch were removed, and a recording disc of glass, lightly smoked, was carried on the post which ordinarily supports the hour hand. Krogh found this instrument too large and too clumsy for his purpose and, therefore, undertook to construct a smaller one on similar principles. Krogh's device was built from a wrist watch 23 mm. in diameter and 5 mm. thick.

The watch-works were mounted in a special circular brass box. The watch is wound by a key, which may be inserted in a hole usually kept shut to protect the works from moisture. The hour-hand post or axle projects into the upper compartment of the box where it supports a brass disc on which the bimetal thermometer and hair hygrometer are mounted.

The temperature sensitive element is a bimetal spiral strip of 3½ turns, the central end of which is securely fastened to the disc. This spiral strip unwinds slightly with increase in temperature and winds up as the temperature falls. The free end of the spiral is connected by a fine silver wire to a small recording lever which amplifies the movement of the tip of the spiral by about three times.

The moisture sensitive element is a single human hair 20 mm. long attached rigidly at one end, while the other end is fastened to a second recording lever. Both levers, at their attachment ends, are formed as small spiral springs and are made of thin sheet brass. At the recording end of each lever a fine needle point has been fixed. These needle points trace thin lines in the smoke on the underside of a flat polished glass

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[1] Krogh, A., A micro-climate recorder. Ecology, 1940, 21, 275-278.

[2] Weichmann's recorder was reported in the above article by A. Krogh (Footnote 1).

disc 27 mm. in diameter, which forms the top of the unit and corresponds to the watch crystal. A third writing point traces a base line for reference in measuring the deviations of the temperature and humidity tracings. The entire unit weighs only 28 grams. The back portion of the box is 33 mm. in diameter and the instrument is 11.5 mm. in thickness.

The environmental air has access to the recording compartment of the Krogh instrument through a number of narrow vertical slots cut in the circular side wall of the round brass box. These slots provide also the needed flexibility in the rim of the watch case so that the smoked glass discs may be inserted and removed. The discs are manipulated by rubber suckers. By this means a smoked disc can be removed from its storage carton, placed on the rim of the case and forced into position. The disc can also be withdrawn from the case rim in this manner and transfered to the microscope stage for reading. The reading stage for the records is a supplement to the ordinary rectangular stage of a microscope and is composed of concentric rings. The inner ring has an opening of suitable size to receive the glass disc and may be revolved. The outermost ring is graduated in degrees, one degree corresponding to 2 min. of record. The record provides for a total duration of 12 hours. A micrometer scale is used in the eye piece of the microscope with low magnification. Methods for the calibration of the Micro-Climate Recorder are described by Professor Krogh.

Applicability of the Krogh Micro-Climate Recorder

The Micro-Climate Recorder was obviously well adapted for the type of use for which it was specifically designed, i.e., to record the temperature and humidity inside the clothing. However, the question pertinent to the present discussion is the adaptability of the Micro-Climate Recorder to the study of emotional disturbances in men who are being taught to fly. For this use the recorder should not be under the clothing but supported near some exposed area subject to mental sweating,[3] probably the palm of the left hand. The method of support and of exposure to the skin must be taken into account in reference to the design of the recorder.

Method of Mounting Recorders

In mounting the recording unit near the palm it was not desirable to place the hand in a leather glove, since this would obviously tend to produce a layer of maximally saturated air around the hand. Only slight changes, either in humidity or in temperature, could be expected under these conditions even though the student pilot might at one time be well relaxed and comfortable and at another time emotional. Measurement requirements, therefore, pointed to the desirability of providing a highly porous pad to serve as an air-filter boundary for the area of skin under measurement. This pad took the form of a ring to support the recording unit near the skin, but without blanketing the area in such a manner as to interfere completely with heat and

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[3] A discussion of "mental" (or emotional) sweating is presented in Part II of this report.

moisture loss from the surface covered. A sponge rubber material was selected that contained numerous capillary channels so that air could circulate through it. From sheets of such material 1.5 cm. thick, discs, 6 cm. in diameter, were cut. A hole, 3 cm. in diameter, was cut out of the center of these discs. This sponge rubber doughnut, with vertical edges, supported the Krogh recorder. When the sponge was not compressed, the glass disc of the recorder, now sunken into the center of the doughnut, was 1 cm. above the surface on which the rubber doughnut rested. A slowly ventilated cavity was thus formed bounded on one side by palmar skin, on the periphery by the porous rubber sponge, and on the other side by the recorder. The doughnut and recorder were attached to the palm of the hand by means of a strap of rubber webbing attached to the slotted openings in the flange around the brass case. Numerous recordings were made by means of a single Krogh unit mounted on the rubber doughnut. Humidity and temperature changes were found to occur and the tracings on the smoked glass disc were readily measurable. The changes were, of course, most pronounced shortly after placing the unit on the hand and again following its removal. Sudden jarring of the hand when wearing the instrument caused sharp spikes in the temperature curve due to the coil spring form of the bimetal thermometer. These disturbances are not so frequent, however, as to spoil the temperature readings possible from the tracing.

The Krogh unit presented one serious drawback for this particular type of use. It had not been designed for ready accessibility of environmental air at the surface closest to the skin. The type of mounting which seemed most suitable for these measurements of skin response placed the Krogh unit at a disadvantage for prompt recording of changes in humidity and temperature. The glass face, which is a better heat insulator than the brass box, is the part naturally placed nearest the skin. The skin heat and humidity must find its way into the indicator compartment via the capillaries of the rubber and through the slots in the sides of the box. A more favorable design would present a well perforated metal surface directly opposite the skin through which air could circulate freely and the skin heat would have direct access to the temperature recording element. Since a choice had to be made between attempting to duplicate the Krogh unit or designing something similar, but more directly adapted to measurements of sudden responses in semi-exposed skin areas, the latter alternative was selected.

The C.A.A.-N.R.C. Micro-Recorder

No one who is acquainted with the excellent characteristics of the many biological instruments designed by Professor August Krogh would lightly undertake to produce an improved model of one of them. The unit about to be described is not to be thought of as such an attempt. It is a similar unit but designed for a purpose which he did not have in view. Although this instrument may be used also as a micro-climate recorder for studying temperature and humidity under clothing, no claim is made that it is better than Dr. Krogh's unit for that purpose. In undertaking the design and construction of the C.A.A.-N.R.C. Micro-Recorder it was of immense advantage to have one of the Krogh units for study and experimentation, and also the benefit of correspondence with Professor Krogh

as well as having the printed description of his instrument.[4]

In planning the design of the C.A.A.-N.R.C. Micro-Recorder for use in measuring the skin responses of student pilots, several features seemed desirable of incorporation.

1. The front of the unit should be perforated with several openings to permit ready circulation of air and direct radiation from the skin to the sensitive elements.

2. The temperature and humidity recording elements should be mounted on the under side of the front plate to bring them close to the skin.

3. Inspection of the record and of the adjustment of the recording needles should be possible without having to open up the instrument case.

4. The unit should have stem-winding and stem-setting features not only for convenience of operation but to provide for separating successive records.

5. The manipulation of the instrument when inserting or removing a record should not require the use of special tools.

In order to realize these desirable features it was necessary to depart from Krogh's design and place the record disc near the center, between the watch movement which revolved it and the recording elements which were given stationary mountings on the front plate.

The watch movement finally selected as motive power for the unit was a standard Waltham, 9 jewel, 8-3/4 ligne, uncased movement, without dial or hands, and supplied with the longest available winding stem and center arbor. The movement had a diameter of 19.5 mm. and a thickness (not including the arbor) of 3.5 mm. A one piece case of special design, with retaining ring and cover all made of brass (bright nickel plated), houses the movement and provides for the mounting and attachment of the unit to subjects during measurement. The form of the case and the general arrangement of the parts which compose the C.A.A.-N.R.C. Micro-Recorder are shown in a scale drawing, Figure 1.

The movement fits the case snugly. No attachment screws are used, but only the pressure from the retaining ring, which is held in place by two screws. The rim of the cover is perforated with seven slotted holes

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[4]The writer wishes to acknowledge generous advice and assistance from Professor C.S. Draper of Massachusetts Institute of Technology, and from Mr. C.E. Mann, a designing engineer, previously associated with the Waltham Watch Company, who was retained part time for service on the project. Mr. Mann, after conferences with Professor Draper and the author, supplied data concerning possible watch movements that could be used, made up trial diagrams and layouts for assembly of all the elements according to submitted details, and supervised the construction of special cases, special tools, and various small parts. For the construction of the recording elements and for the final design, assembly and adjustment of the C.A.A.-N.R.C. units, the author himself was responsible.

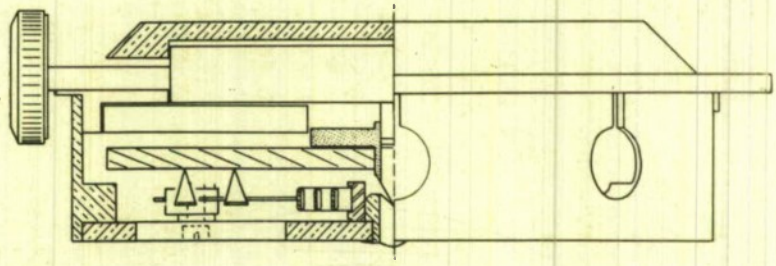

Figure 1
Cross section Drawing of the C.A.A.-N.R.C.
Micro-Recorder Showing Form of Case and
Arrangement of Parts
(Reproduced about 3X actual size)

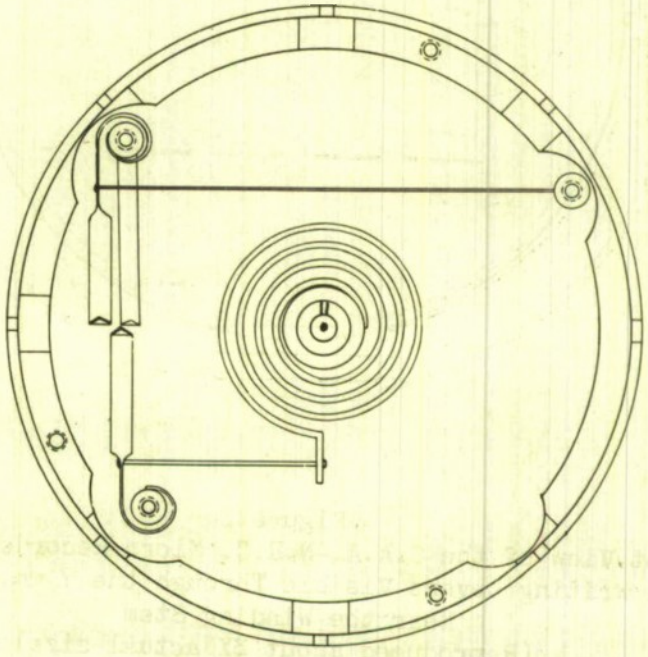

Figure 2
Drawing Showing the Layout of the Temperature,
Humidity and Base Line Recording Units Mounted
on the Under Side of the Front Plate
(Reproduced about 3X actual size)

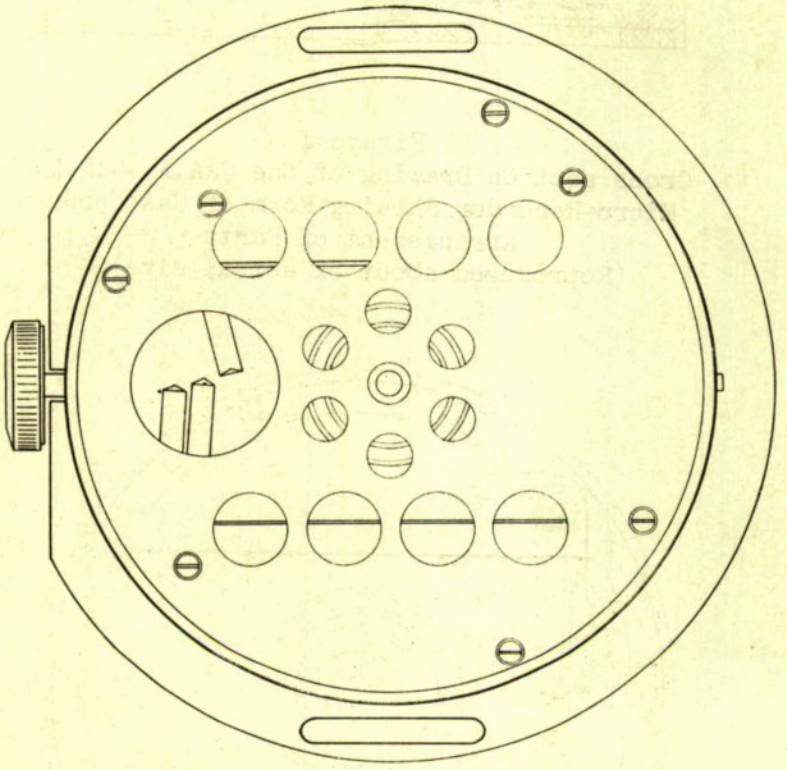

Figure 3
Front View of the C.A.A.-N.R.C. Micro-Recorder Showing the Writing Levers Visible Through the 7 mm. Opening Near the Winding Stem
(Reproduced about 3X actual size)

3.5 mm. in diameter (not shown in the figure). It is therefore flexible at the free edge and with a little pressure snaps over the protruding collar on the case. A small pin extending from this collar directly opposite the winding stem and a notch in the cover serve to give the cover a fixed position when in place on the case. The rim of the cover is 6.2 mm. high and 28 mm. in diameter. (This is the portion that projects into the rubber sponge when the unit is mounted on the subject's hand.) A flange, made as a part of the case, extends 3 mm. laterally from the rim of the cover. The unit is suspended on this flange as it rests on the supporting sponge pad.

The front plate (see the scale drawing reproduced as Figure 2) fits flush with the top of the cover ring and is attached to it by means of three small screws. This plate is perforated with 15 holes to permit of ready circulation of air around the recording elements. (These perforations do not appear in Figure 2.) A group of 6 holes, each 2.5 mm. in diameter, is placed near the center directly exposing a large portion of the bimetal thermometer. A line of four 3.5 mm. holes directly exposes most of the length of the hair used as the moisture indicator. A single opening, 7 mm. in diameter, exposes the tracing ends of the small levers to view after the case has been closed. Through the window the operator may assure himself that the levers are making suitable tracings on the smoked disc.

The details of the recording elements for temperature and humidity mounted on the inner side of the cover plate are illustrated in the scale drawing, reproduced as Figure 3. The temperature element is made of a strip of "Truflex A" bimetal strip .010" thick by .048" wide by $3\frac{1}{2}$" long.[5] These were coiled in spirals of 3 turns with the right-angle, outside tips (0.1" in length) pierced with a small hole. After being formed into a spiral the bimetal was heat-treated at 300° F for a period of 3 hours.

A center post attached to the front plate, serves as support for the bimetal spiral. The mounting was made by means of a small, slotted, brass spool with narrow flanges at the top and bottom. The separation between these flanges is just sufficient to admit the 0.048" width of the bimetal strip which is fastened by soldering. The spool is forced on the center post and held in place by friction. By means of a screw driver inserted in the open slot of the spool, it (and the spiral) may be turned to any desired position.

The recording levers are made of 0.002" spring brass sheet cut into strips of 0.05" wide. Small threaded brass spools with thin flanges are used for attachment. The lever strip is first soldered lightly to the spool between the flanges, then rolled around the spool loosely for $2\frac{1}{2}$ turns. At a distance of 2 mm. from the center of the spool a small hole is made in the strip. Through this hole a small wire connects the recording lever with the free end of the bimetal spiral. Beyond the connection

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[5] The "Truflex A" bimetal strips were procured from the General Plate Company, Attleboro, Massachusetts. They coil- and heat-treat them to order.

the lever is twisted so as to increase its flexibility at right angles to the recording surface, and the top is sharpened and bent down so as to form a thin tracing point. The spool supporting the writing lever is fastened to the front plate by a watch screw and held in position by friction of the spool against the plate. Finer adjustments in the position of the lever can be made by slight rotation of the spool attached to the bimetal spiral.

The lever for the humidity element is of similar design to that used for the temperature recorder. It is attached to a piece of human hair that has an active length of 20 mm. One end of this bit of hair, after being passed through a small hole in the lever, is tied in a knot. The other end is clamped by means of a small cylindrical nut held to the front plate by a watch screw. The clamping must not be so tight or the nut so sharp as to cut off the hair. Carefully selected, thin, smooth human hairs are soaked in purified gasoline for 24 hours and washed with ether, alcohol, and distilled water before being mounted.

A third and fixed lever for inscribing a base line is clamped against the plate under the spool which supports the lever for the humidity element. The position of the three levers and tracing points is so adjusted that the levers do not interfere with each other's action.

The Problem of the Recording Disc[6]

The recording disc and its mounting have occasioned the major difficulty in design of the C.A.A.-N.R.C. Micro-Recorder. Several modifications of one sort and another have been tried. The arrangements shown in Figure 4 are not regarded as optimal although they are workable. The watch movement has ample power to drive the disc against the friction of the three recording needles. The arbor is quite accessible but is not by itself suited to support the recording disc. It had to be supplemented by a retaining disc, D1, made of bronze, 9 mm. in diameter and .07 mm. in thickness. This disc is so formed as to have a center pivot shoulder 1.7 mm. in outside diameter, for centering and holding the perforated smoked disc, D. This pivot shoulder was bored out to receive a short section of drill rod, the upper end of which was formed as a conical bearing point.

To the underside of the retaining disc a small hour-wheel adapter gear, D2, is attached concentric with this disc. The retaining disc with shoulder, pivot bearing point, and gear wheel, constitutes an assembly

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[6]It is no doubt clear to the reader that the construction of a Micro-Recorder from first to last must be a "jeweler's job." The parts have to be made with essentially the same precision and size tolerance required in good watch work. The unit must be adjusted and used with care and skill similar to that which would be lavished on a good watch. In the description the reader has been spared going over many details about materials, dimensions and construction which can be supplied to any who may be interested. Glass record discs would be preferable to those made of plastic but they were not procurable.

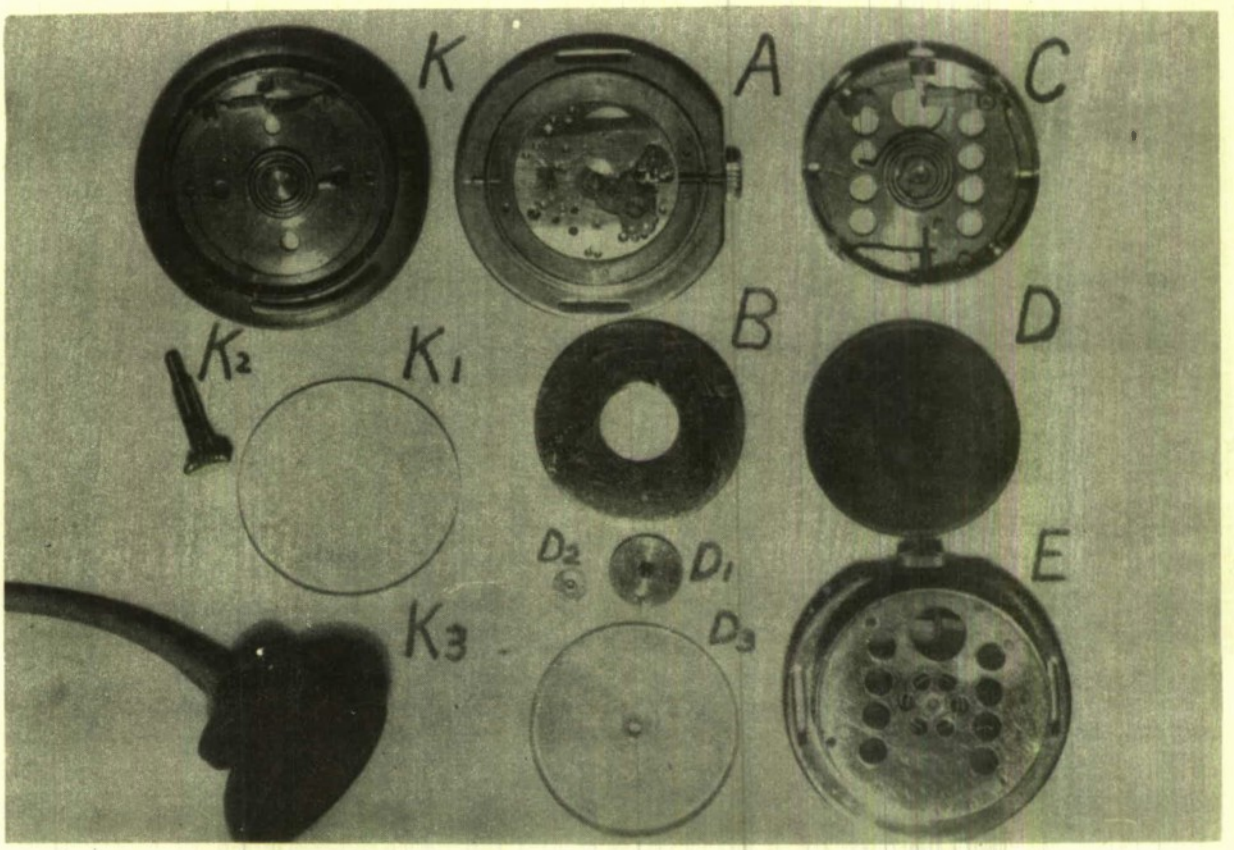

Figure 4
Comparison of the Krogh Micro-Climate Recorder and the C.A.A.-N.R.C. Micro-Recorder
(Photographed slightly larger than the actual size)

K ——Front view of Krogh unit
K_1 ——Krogh record glass
K_2 ——Krogh winding key
K_3 ——Krogh sucker for manipulating records
A ——C.A.A.-N.R.C. unit showing watch movement in case
B ——Retaining ring
C ——Inside cover showing temperature, humidity, and base line recorders
D ——Record assembly
D_1 ——Bronze retaining disc with pivot shoulder
D_2 ——Hour-wheel adapter gear
D_3 ——Unsmoked Lucite record disc
E ——C.A.A.-N.R.C. unit completely assembled and ready for use

which can be slipped over the arbor and forms a light friction fit with it. The gear on this assembly meshes with a gear of the watch movement. The retaining disc can be slipped on or taken off at will. It provides for centering and supporting the record. The sharp pivot point projecting from the top of the retaining disc seats in a metal jewel formed in the core of the center post on the front plate (shown in Figure 4, C). This center post end-bearing is made of a piece of drill rod 1/8" long. It forms a tight fraction fit in the tubular center post of the front plate and its position may be adjusted to regulate the amount of end play. When the cover of the case is snapped into place, the pivot point of D1 seats in this V-shaped recess in the center post, and the record disc, now held securely in a position horizontal to the case, may be freely turned by the watch movement.

The recording discs, D3, accommodated in this unit are 25 mm. in diameter and are perforated at the center with a small hole to admit the shoulder of the bronze retaining disc. In the first experimental trials, discs made of Lucite sheet .032" in thickness were pressed onto the bronze shoulder to fit snug and flat against the upper surface of the retaining disc. It was found that the pressure of the shoulder at the center of the disc soon caused it to loosen its flatness and assume the shape of a shallow saucer. This modification of the surface also occured when the discs were made of Lucite as thick as .040". Therefore, it seemed best not to depend on a pressure fit but to use a slightly larger hole in the center and to cement the record disc to the bronze retaining disc. This introduces something of a limitation since it does not permit of rapidly changing from one recording disc to another for use in the same Micro-Recorder unit. However, it is a workable scheme since the records usually do not last longer than an hour and several can be inscribed on the same disc in succession by the simple expedient of stem setting and making supplementary notes.

The record discs are very lightly smoked on one side over a candle or small kerosene lamp. Several discs can be prepared in advance and stored in a small box which has a center post to hold them in order. They are kept separated by small washers. Rubber cement or any one of a number of varieties of cement are suitable for attaching the recording disc to the bronze retaining disc. Several units may be completely arranged in advance for use at an air field. It is expedient first to let the watch movement run down and stop so that when the recording disc is put in place and the case closed the unit will not run until the operator is ready to use it, at which time he winds it up and starts the movement.

Each Micro-Recorder demands separate calibration and any results of field tests must be interpreted in reference to its own calibration chart.

Calibration of the C.A.A.-N.R.C. Micro-Recorder

The calibration for temperature is not difficult. Several recorders are placed in a small water tight box which is immersed in a constant temperature

bath regulated by a thermostat.[7] The bath is equipped with a stirring device. A high-grade thermometer, calibrated to 0.10° C., is placed in it with the bulb near the box. By setting the thermostat to different readings and keeping it at any single reading for about 2 hours, a series of representative temperatures may be applied to the recorders. The results for the several recording discs may be read and charted separately for each recorder unit.

The bimetal thermometers are dependable and quite stable. Each spiral is of course under somewhat different tension and by its recording lever has slightly different magnification but for a given instrument the results are consistent and have an accuracy of ±0.20° C.

The hair hygrometers must be calibrated differently and in a manner that is necessarily more intricate, and less accurate. The units are exposed to 100% moisture by wrapping them in several layers of wet filter paper or in wet linen towels. Other points on the humidity scale were most conveniently supplied by following the method outlined by Krogh.[8] This method takes advantage of the fact that well defined moisture percentages are established over saturated solutions of water absorbing salts. $MgCl_2$ at 20° C., gives 33% humidity and at 40° C., 35% humidity; K_2CO_3 at 18.5° C., gives 44%, and at 24.5° C., 43% humidity; NaCl at 20° C., gives 76% and this is almost independent of temperature. When calibrations are made at 22-25° C., the corresponding moisture percentages can be taken as 33 for $MgCl_2$, 43 for K_2CO_3, and 76 for NaCl. Humidity measurements with the hair hygrometer element indicate an accuracy of within about 5% in the range of 75% to 95% moisture, and for the lower ranges an accuracy within 2% to 3%.

The chemicals used for calibrating the hair hygrometers were placed in dessicators and the instruments, without being boxed up, were placed on a porcelain shelf and inclosed with the chemicals for 3 or more hours. The difficult part of this procedure is in adding just the right amount of moisture to the chemicals so they can be molded into a large irregular mass without the occurrence of fluid surfaces. For further details of the methods of calibrating such instruments reference is made to Krogh's article.[8] A dessicator is a suitable receptacle in which to keep the Micro-Recorders when not in use. This is chiefly for protection of the hygrometers. They should not be allowed to dry out and every few days should be exposed to 95% moisture to keep them in good working order. Otherwise new hairs must be mounted and new calibrations made.

After calibration, the position of the bimetal spiral, and the form of the tracing levers for temperature and humidity, should not be changed.

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[7] A precision temperature regulator made by the Eastern Engineering Company, New Haven, Conn., was used. This regulator makes use of a number of sensitive liquids which give a very adequate range. The arrangement employed regulated to within ±0.05° C.

[8] Krogh, A., op. cit.

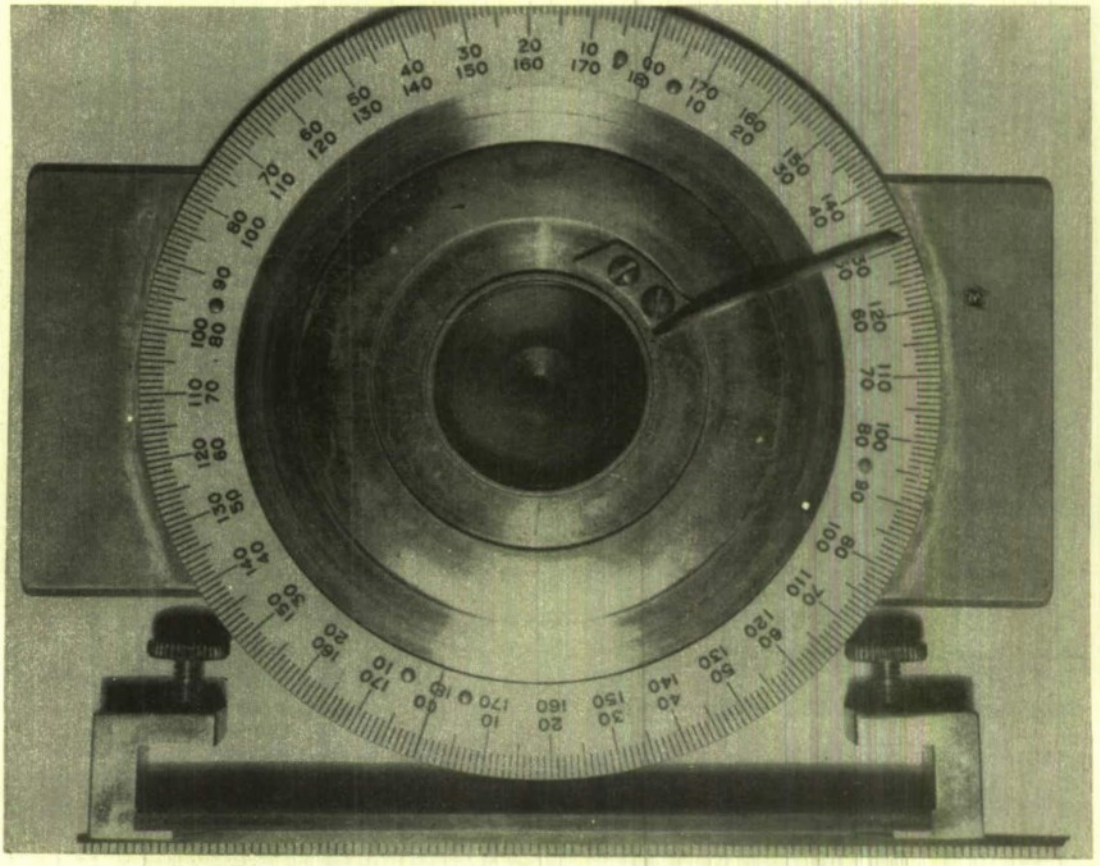

Figure 5
Special Stage for use in Reading the C.A.A.-N.R.C.
Micro-Recorder Records

One of the clamps for fastening the stage to the microscope is shown. The scale at the bottom of the illustration is in millimeters. The record supported in the central ring may be turned by the attached arm which serves also as an index against the protractor scale. One degree equals 2 min. of time.

The watch movement, however, may be regulated for this cover is taken off, the record disc taken out, and the retaining rim, B, is removed. Then, by means of the winding stem, the works are lifted out and turned over for access to the regulator arm. This disassembly plus the reassembly after regulation requires only two or three minutes. Runs for checking record-disc speed by means of smoke tracings for three or four hours are used. An assembled Micro-Recorder ready for use is illustrated in E of Figure 4. The unit has a total weight of 26 grams.

Reading the C.A.A.-N.R.C. Micro-Recorder

Most thermometers and hygrometers are currently made as direct reading instruments. This is a convenience greatly to be desired but is not feasible for the Micro-Recorders. The circular record inscribed by this tiny instrument must be magnified if useful quantitative data are to be gotten from it. Two methods of magnification are available. First, quantative readings may be made by means of a microscope, fitted with a suitable stage (see Figure 5) and with a micrometer scale in the eye piece. Second, large permanent records can be made with a photographic enlarger such as is commonly used for Leica or other miniature camera films. The microscope method is the one recommended by Professor Krogh. This method was used in securing the data presented and discussed in Part II of this report.

The enlargement method is feasible and has also been used by the author. It employs a transparent protractor disc 25 mm. in diameter made of negative film. This disc has an opening in the center. The record and the protractor are placed concentric in the enlarger so that the print shows the tracing and the degree scale. Enlargement has one special advantage, in that copies of the tracings are available for filing with the notes and for reproduction when desired.

PART II

Preliminary Experiments with Student Pilots

"Mental" Sweating

It is sometimes observed that emotional disturbance tends to produce sweating, especially at the axilla, on the soles of the feet, and on the palms of the hands. "Mental" or emotional sweating, when it occurs, tends to appear at all three surfaces and on both sides of the body. There are considerable individual differences among people when they are measured under what are arranged to be objectively similar circumstances. Mental sweating also tends to occur under a rather wide range of environmental temperatures. According to the classical work of Krause,[9] who studied the distribution and number of sweat glands on the human body, the palm of the hand and the sole of the foot, contain per unit area, more than twice as many sweat glands as are found for the forehead. The forehead itself is very richly supplied with sweat glands in comparison with the general surfaces of the body.

By use of the fuschsine dye method, Minor[10] who devised this technique, and others,[11] have produced most interesting photographs showing the relative distribution of the sweat glands on the palm and on the sole of the foot. The dyestuff when dry is a white-green crystal powder that can be dusted on the skin surfaces quite easily. When sweating occurs the moisture dissolves the crystals and yields a brilliant dark red coloring matter. By this method it has been found that the palmar line curving around the base of the thumb comes out almost colorless, indicating very little sweating. However, beginning near this line and on either side the deep coloring indicated profuse sweating on what may be termed the large protuberant regions of the palms. The color tended to be darker on the fingertips than on the other parts of the fingers. From this general picture it was demonstrated that the parts of the palm which come into close contact with objects grasped are those parts which tended to produce the greatest amount of sweating. The center of the palm although not the most richly supplied area was for practical reasons the place of choice for location of the Micro-Recorder.

Skin Temperature Changes

Emotional or mental tension not only produces sweating strikingly ob-

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[9]Krause, K. F. Th. Wagner's Handwörterbuch der Physiologie, 1844,2,131.

[10]Minor, V. Ein neues Verfahren zu der klinischen Untersuchung der Schweissabsonderung. Z. ges. Neur. Psychiat., 1927, 47, 800.

[11]Kuno, Y. The Physiology of Human Perspiration. London: Churchill, 1934, Pp. 268.

servable on the palms and the other areas mentioned; it also produces some change in the skin temperature. The result may be a rise, if there is dilation of the capillaries and arteriols and increase of blood pressure resulting in increased circulation, or a fall, if there is constriction of the arteriols and the closing of some of the capillaries. The temperature of the skin is modified by the vaporization of the sweat and hence by the circulation of air over the skin.

From the large amount of evidence about palmar sweating and temperature change due to emotion or to the stress of mental work, such as is involved in mental arithmetic,[12] these areas appeared to be particularly suitable for study in student pilots.

The C.A.A.-N.R.C. Micro-Recorder is designed for use in examining the responses of palmar skin areas during flight. It needs only to be held in some suitable support near the palm of the hand, but not against it. In this position it is influenced by changes in the humidity of the air immediately over the semi-blanketed skin area and by changes in temperature that might occur due to changes in circulation. The recorder in position as worn on a subject's hand is shown in Figure 6. The ring (doughnut) of porous rubber sponge supports the recorder at a distance of 1 cm. from the underlying skin. The temperature element is influenced by both conduction and radiation.

Experimental Arrangements

Arrangements were made to conduct tests at a school giving CPT training to Yale University Students.[13] A total of 14 students was theoretically available for this study, but since it was impossible for the laboratory assistant to be at the field continuously during all of the flying hours, records on all of the men were not secured. The instruction hour schedule for the Yale students (designated by letters A-N) is shown in Table 1.

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[12] Kuno, Y., op. cit.

[13] Lufberg Flying School, Inc., Wallinford, Connecticut, Mr. R. D. W. Vroom, president and flight contractor for training. The author wishes to express cordial appreciation for Mr. Vroom's kind cooperation during the period in which it was possible to conduct the tests, i.e., until flying close to the Atlantic Coast had to be discontinued.

It must be noted, however, that despite the fine cooperation given the study by Mr. Vroom, the instructor at the airport was not enthusiastic. On the whole he was rather unfavorable to the idea of conducting any experimentation in connection with the flight training. What he may have said to the students in regards to the test is not known. It had been planned to have the instructor wear one of the C.A.A.-N.R.C. Micro-Recorders regularly as a control for the student's record. This proved not to be possible as the instructor did not choose to cooperate in this manner.

Acknowledgment is also made of the faithful services of Mr. Leonard Taddei, laboratory assistant, who attended to taking the records at the flying field, and who read and tabulated the results.

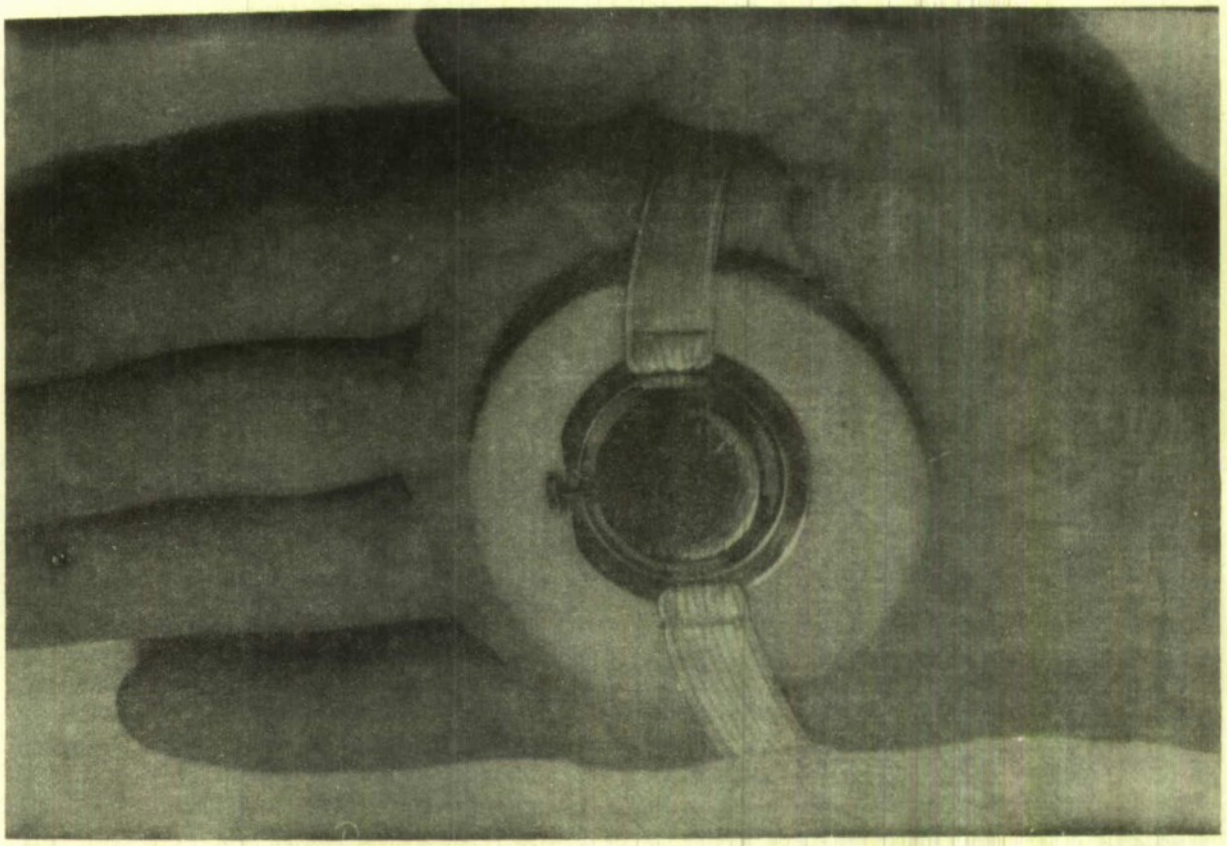

Figure 6
The C.A.A.-N.R.C. Micro-Recorder Mounted on the Hand

Student K had finished CPT training and had received his solo license. Students N and L were both private students. Student M had finished CPT training, but after 74 hours flying (up to Nov. 4, 1941) had still failed to secure a private license. The others were regular CPT students. Examination of Table 1 reveals that instruction was given on all 7 days of the week, and in general, that 45 minutes appear to be allowed for each lesson with 15 minutes between for servicing the training craft. Actually the lessons were 30 minutes as a rule and between CPT lessons private students were fitted into the day's program. Two-passenger, dual control Taylorcraft planes were used in this training program; three planes were usually available. The training period extended from October 20 to December 2, 1941. This covered from the beginning of training for these boys until near the end of their training.

TABLE 1

INSTRUCTION HOUR SCHEDULE
FOR YALE C.P.T. STUDENTS

Time	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
8:00 A.M.-8:45 A.M.	A	H	A	H	A	H	B
9:00 A.M.-9:45 A.M.	B	I					G
10:00 A.M.-10:45 A.M.	C		C		C		A
11:00 A.M.-11:45 A.M.				I	E	G	E
12:00 A.M.-12:45 P.M.		I				B	G
12:45 P.M.-1:30 P.M.	D	D	D	D			
1:30 P.M.-2:15 P.M.	E	H	B	E	I		J
2:15 P.M.-3:00 P.M.	F	F	F	F	J		
3:00 P.M.-3:45 P.M.	G	C	J				
3:45 P.M.-4:30 P.M.		J					

This particular training field was located in a valley between two ranges of hills. The field was of average size, flat and covered with firm sod. It presented no unusual hazard, and the air traffic around it was very light. Usually not more than two or three planes would be in the air in this vicinity at one time. No accidents of any importance occurred during the weeks covered by this training. The school had a very excellent record in reference to accidents.

Connecting with the hangar and adjoining office buildings there was a waiting room where students came to check in before taking their lessons. The room was comfortably furnished with lounge chairs, and was heated by steam radiators. It was in this room usually that the Micro-Recorders were placed upon the students when they first came for their day's lesson.[14] Following the lesson the students returned to the waiting room to sign the log book and converse with the instructor as he made out the flight jacker. Following this, when they were ready to leave the field, the Micro-Recorder was removed.

During their training flights students always wore parachutes but no other special flying clothing. They wore ordinary shoes and trousers, and in place of coats and vests or overcoats, wore jackets. No gloves or mittens or helmets were used. There were never any open cockpit windows. While the waiting room temperature was comfortably warm, the outdoor temperature and humidity varied considerably from day to day. The data on temperature and humidity, taken from the local weather report, are presented in connection with the records.

In introducing the instrument and the test to the subjects, it was called simply a "temperature recorder." The real objective of the test was not described or discussed. The student was told to treat the instrument like a watch and in general try not to smash it. He was asked not to keep his hand closed tightly around the instrument and sponge, and not to try to keep his hand flat open, or alternately opened and closed, squeezing and releasing the sponge. He was to forget it and use his hand on the wheel in as nearly the usual manner as possible. Notes were made in reference to each flight studied. These included the subject's name, date, time, recorder number, the exact time when the subject got into the plane and started taxiing, the time when the plane landed, the time when the recorder was removed.[15] Each student was always questioned at the end of the flight in reference to any special events that might have occurred, but in general this questioning revealed little in the way of significant data except to show when a lesson was devoted chiefly to practicing steep turns, spins, and landing.

Review of Representative Records

In order that the reader may have a first-hand impression of the records secured with the C.A.A.-N.R.C. Micro-Recorder used in connection with flight training, 20 records are reproduced in the following few pages (Charts 1, 2, 3, and 4). The records have been enlarged 6½ times. The subjects are designated by letters. For some subjects groups of records are shown, for others

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[14] They usually arrived five or ten minutes early. Most of them came by auto from New Haven, about 12 miles distant. Subject N came from Meriden, 5 miles, and Subject K from Middletown, about 17 miles away.

[15] At first it was thought the assistant might watch the plane during flight and make notes concerning maneuvers and the time when they occurred. This proved impractical as the planes usually went off some distance from the field and were frequently lost to view.

single records. Opposite each record the essential data tabulated from it are given. In the first line appears the subject's letter designation, the date, the recorder number, the weather report for temperature, humidity, and wind for the time of day nearest that of the flight lesson, and finally the training plane that was used. The second line gives the time record; S for start of the record, E, entering of plane, usually promptly followed by take-off, L landing of plane, and R removal of the recorder from the subject's hand. The third line (T C°) shows the temperature readings and the fourth line, (H%) the humidity readings. Each reading given represents the time indicated above in the second line. A horizontal line connecting two readings indicates that this value was substantially constant for the period represented. Following these data, brief notes have been entered indicating the type of training given in the lesson and other pertinent comments.

The first and most general observation noted in these records is that both temperature and humidity are variable during the periods represented by the records. Secondly, it is obvious that the temperature recorder is more sensitive and gives a larger deflection than the hygrometer. Therefore, to the eye the temperature appears to change more than the humidity. The coil spring form of the bimetal thermometer makes this unit also more subject to response from vibration.

In almost all the records, as would be expected, rises in temperature and in humidity are shown in the first minute or so after the recorder was placed on the subject's hand. For general inspection each tracing can be interpreted in terms of its own form, but the readings are always made from the base line labeled, B. The rise in humidity is more prompt than that for temperature. The latter gives a rather gradual change. Following this preliminary elevation, the two curves may show roughly parallel tracings, each rising or falling during a particular interval, or they may diverge, one showing a rise while the other falls or indicates substantially no change. Although temperature and humidity over the area of palmar skin that is being studied represent two related phases of neuro-physiological processes active in the tissue and in the body as a whole, these phases are not necessarily highly and positively correlated. If the palmar skin area was completely uncovered an increase in sweating would logically be followed by a decline in skin temperature due to cooling from evaporation. The porous rubber sponge mounting retards air movement and evaporation is slowed down. Sweating may therefore occur and skin temperature may rise. Tests in the laboratory have shown that wearing the recorder for 10 minutes when the hand is bare, but quite warm (34.3° C.), causes a rise of about 1.0° C.

In some instances it is evident that when the subject left the waiting room and went to the plane, there was a fall in temperature. Probably this is to be credited to the sudden change in environmental temperature for the subject's body as a whole, resulting in a general constriction of the skin capillaries. Decreases in humidity at the time of going to the plane seem less pronounced.

The humidity curves during the period of flight appears to be fairly regular, although they sometimes show obvious small waves. The temperature curves, because of the construction of the bimetal thermometer as a spiral

with one end free to vibrate, show many instances of pronounced vibration of the recording lever. These widened portions of the curves are particularly prominent at times corresponding with taxiing and landing the plane. They also seem to occur quite frequently from sudden movements of the subject's left hand, or from impact of vibration communicated to the left hand.

Usually there is a change in both temperature and humidity closely associated with landing. Sometimes these changes just precede that event; at other times they follow it. Unfortunately, as explained earlier, it was not possible to secure intimate details of behavior data for temporal correlation during flight and in connection with the landing. We must therefore be satisfied with a general view of what the experience of flying does to the responses in the skin.

Records 1 to 4 (Chart 1) represent four different students: Subject K (Record 1) was not a novice (he had his solo license) but even so he shows temperature and humidity changes during the one hour of flight represented. The temperature and humidity were actually highest just before he began his flight. After he had taken off and been in the air for about ten minutes the temperature slowly fell and the humidity also declined. There were periods, however, when both curves tended to rise again. At the time of landing his temperature was at the lowest point shown. From here it gradually rises. The humidity however, rose at the time of landing and made no special change after that.

Subject I (Record 2) had taken about one-third of his flight course. The weather humidity was moderately high (70%) while over his palm the record gives 48.5% as the highest during flight. The temperature curve is quite even, but the humidity line shows several small waves. Following landing, both curves rise.

Subject G (Record 4) was taking his second flight lesson. This was, in fact, the second record taken at the field. His temperature rose irregularly throughout the entire flight period, and the humidity line remained quite consistently smooth and relatively high, falling promptly after landing.

Subject N (Record 4) had about six hours of flying. His lesson was relatively brief. Attention should be called to the upswing in the temperature curve, also in the humidity curve, which occurred several minutes prior to his flight. This is coincident with a conversation he had with the flight director, in the presence of the assistant, and during which he seemed to be emotionally upset by the change in plans which the director told him must be followed.

Records 5 to 8 (Charts 1 and 2) represent four flights for Subject H, taken at different periods in his C.P.T. training, but all with the same recorder (No. 36). Record 5 (Chart 1) represents his second lesson. It was uneventful, he was practicing level flight. The temperature curve rises progressively throughout the flight with little or no change until the very end, giving a quick descent after landing. Humidity rises a little slowly at first,

but remains consistently high and even throughout the flight with a fairly prompt decline following landing. Record 6 (Chart 2) shows a lowered temperature probably related to the fact that the environmental temperature was 6.7 on this day, compared with 18.3° C. on the day of the previous record. During flight the temperature curve rises, but not as prominently as in No. 5. Landing is not followed by a fall in temperature, but after four or five minutes there begins a prominent rise which continues for some time. This is associated with entering the waiting room. The recorder was removed from the student and the continuation of the record marks the adjustment of the instrument to room temperature. The humidity curve during flight shows some undulations, but following landing tends to be somewhat higher. Record 7 (Chart 2) represents a lesson in which landings and take-offs were practiced. The humidity line is fairly constant during pre-flight, flight, and post-flight periods. At the time of entering the plane there was a sharp decline in temperature followed by the irregular rise which continued through the flight and held its general level following the flight. Landings seem to have been executed rather smoothly since there is no clear indication of them in the temperature record. This is not true for the same recorder when tracing Record Number 8 (Chart 2). This was a long lesson, (the entire record is not reproduced) as the notes indicate, during the latter part of which the student soloed, and was considered ready for solo license. It is interesting to note that the humidity line in this record is the highest in general for the four records representing this subject. While he was soloing he hit the top with 100% humidity, and his temperature record also seems to have been at its peak for that day, although not higher than on other days. This may be an expression of the cooling effect produced by the sweating. Following final landing the temperature rose still higher, while the humidity remained at 100%.

The three Records 9 to 11 (Charts 2 and 3) inclusive are all for Subject D and were taken with the same recorder (No. 36). These were all representative of the second half of the course for Subject D. In Records 9 to 10 (Chart 2) the student was practicing landing and taking off. Indications of landing seem to be present. The humidity curve bumped the top of 100% regularly for this man. The temperature curve tended to rise throughout flights represented by Records 9 to 10 and to be still higher following the flight, while the humidity went down. In Record 11 (Chart 3) Subject D had a fairly long flight, 50 minutes. The plane was landed during this interval, the instructor left the ship, and the student was allowed to solo. The record is not a particularly legible one, but it seems to indicate that he got along nicely. He was probably doing considerable mental sweating as the humidity was 100% for 16 minutes during the latter part of the flight, while the temperature curve remained at 29.7. Following landing the temperature curve quickly rose to 31, and the humidity fell off to 86%. It is noteworthy that the first solo flight of Subject D seems much less emotionally eventful than does that of Subject H (Record 8). Both records were taken with the same recorder, and under closely similar environmental conditions, temperature 12.2° C, humidity 78%, the same wind conditions, and the same plane.

These records for Subject E are included as Numbers 12, 13, and 14 (Chart 3). The first two were taken with recorder 36, the last with recorder number 2. No special comments are necessary except that judging from the temperature and the humidity during flight, the strain seems to be greater on the subject in Records 13 and 14 than in Record 12. The last two records were

probably more trying, since the subject was practicing landing and taking off.[16]

Records 15 to 20 (Charts 3 and 4) inclusive are all for subject F. Number 15 (Chart 3) came at the very first of his course, and number 20 at the very end. It is noteworthy that oscillations in the curves seem rather to increase with the progress of his training. Perhaps this is the general picture that should be expected if a relatively large number of tracings are taken representing the entire course. At the first the subject may be almost continuously tense and emotionally wrought up. As he progresses his periods of tenseness may be interrupted by periods of relative relaxation and ease reflected by oscillations in the traced curves. In order to prove such a statement, it would certainly be necessary to have a detailed account from the instructor. How or why the humidity curve shows such a sharp and relatively square notch as is indicated in Record 17 (Chart 4) just prior and after the interval of entering the plane, is at present wholly unexplained. The precipitant drop in humidity in the few minutes just preceding landing (Record 17) associated with the rise in temperature is also difficult of explanation. If it may be assumed that changes in temperature and sweating represent emotional responsiveness then Subject F certainly seems to have experienced these conditions both before and during the lesson in which he was permitted to solo, which is represented by Record 20.

In general, for the records at our disposal, it seems that the solo lessons give the best illustrations of rapid temperature and humidity modulations whereas the first or very early lessons give the smoothest and most regular curve.

Review of Grouped Data

From the preliminary investigation carried out by use of C.A.A.-N.R.C. Micro-Recorders it is possible to present only very general findings. No grades or ranks on the students for tension or relaxation were available. The instructor regarded the tests as an interference with his work and could or would not lend cooperation. All the CPT students were just beginning their training. The school was a small one, air traffic was slight, and other conditions favorable. All the training was by the same instructor. Three dual control Taylorcraft planes were used.

It seems possible to group the results and present them in tabular form. The following Tables, 2 to 10 inclusive, are all similarly arranged. The recorder tracings for each man have been divided into three chronological portions, representing the pre-flight, flight, and post-flight periods. The duration of the flight period varied somewhat, but not as greatly as did the

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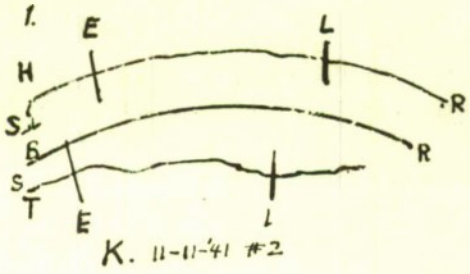
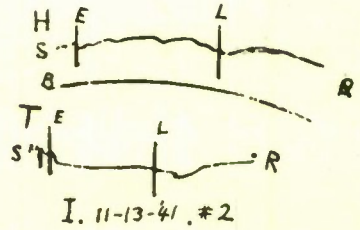
[16] A curious portion exists near the middle of the flight record for number 14 where a large and continuous amount of oscillation of both tracing levers is shown for a period of about 10 minutes. It is tantalizing not to know the meaning of such features of these tracings, and the writer feels most apologetic for these gaps in the information that should be available both to him and to the reader.

1.



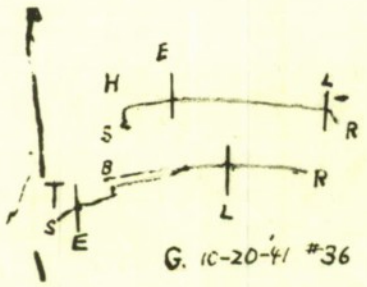
Subj-K: 11/11/41,#2,5A.M.6.7°C,58H,W-4,NC27644
S1:45P.M. 1:56 E2:02 2:30 2:45 L3:02 3:17R3:32
TC 32.0 29.2 29.2 23:5 23.5 18.7 22.7 27.3
H% 33 97, 97, 97 92.5 85,94, 94 88,97, 94
Note: This subject had his solo license.

2.



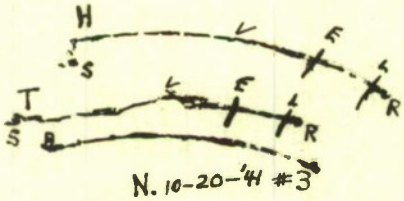
Subj-I: 11/31/41,#2,8A.M.5.0°C,70H,Calm,NC27646
S8:57A.M. 8:59 E9:02A.M.9:15 9:27 L9:35 9:47 R10:05
TC23.5 21.7 17.9 15.0 15.0 14.5 13.2 17.3 22.2
H% 36, 33 33 37, 48.5,39,58,43 58, 79
Note: Usual procedure: Level flight.

3.



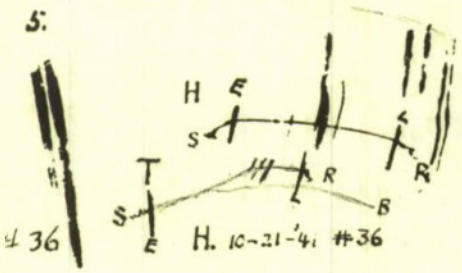
Subj-G: 10/20/41,#36,5P.M.15.6°C,57H,SW-8,NC29590
S3:45 E 3:55,4:02,4:19 4:25 L4:30 R4:32
TC25.2 25.7 27.3 29.5 31.0 31.0 32.4 32.4
H% 33,82,77.5 86 (33min) 86 77.5 77.5
Note: Practiced level flying. Plane took off, made first turn at 500 ft., rose to 1000 ft., minor necessary turns taken at 1000 to 1500 ft.

4.



Subj-N: 10/20/41,#3,5P.M.15.6°C,57H,SW-8,NC29590
S4:05, 4:34,4:45 E4:55 L5:15 R5:18
TC28.0 26.0 30.0 28.0(20 min) 28.0(3 min)28.0
H% 40 92 100 94 88.5(20 min) 88.5(3 min)88.5
Note: Landed and took-off twice during period. This subject's readings run normal continuously for thirty-five minutes, then there is a sudden rise, believed due to a conversation with Mr. Vroom regarding a change in his flying schedule. Has had some hours of flying, about 6.

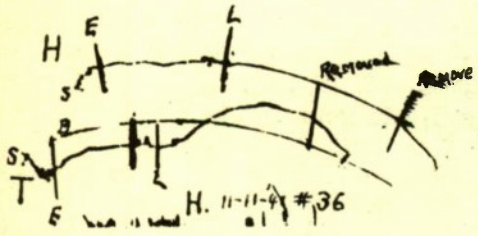
5.



Subj-H: 10/21/41,#36,5P.M.18.3°C,75H,SW-5,NC29590
S2:00P.M. E2:05P.M.,2:16,2:32,2:42,L2:44P.M.R2:47P.M.
TC28.6 28.0 31.0 34.0 34.2 32.3 31.0
H% 42, 64.5, 86,82 (37 min) 82 68.5
Practicing level flight.

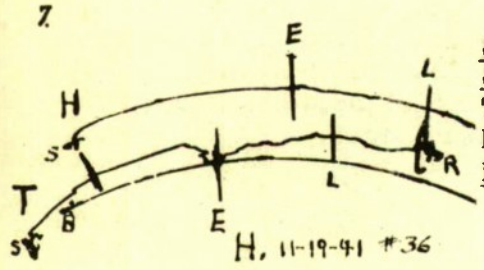
CHART 1
C.A.A.-N.R.C. Micro-Recorder Records 1-5

6.



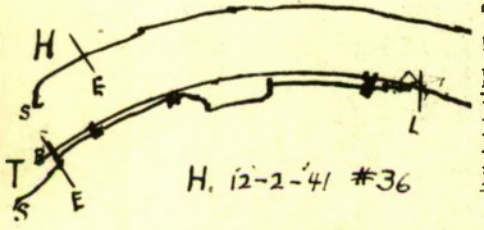
Subj-H: 11/11/41,#36,5P.M.6.7°C,58H,W-4,NC27646
S1:26P.M.1:28,E1:34P.M.1:46,1:58,L2:05P.M.2:21 R2:50
TC28.4 22.3 23.9 24.4(12 min)24.4 23.1 29.1 35.2
H% 33,86 86 90, 82 91 91
Note: Recorder removed from student and left to continue under "waiting room" conditions. Practiced level flying.

7.



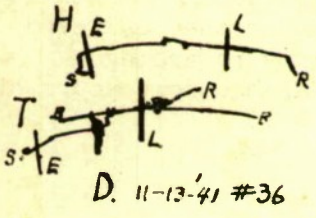
Subj-H: 11/19/41,#36,8:00A.M.11.1°C,64H,SW-6,NC27646
S2:55P.M. 3:05,3:35E3:45 L4:15 4:23 R4:41
TC25.7 29.5 34.4 29.1 34.4 34.4 34.0 35.2
H% 33, 86 91 86 (30 min) 86 91 88.5
Note: Landings and take-off's were practiced.

8.



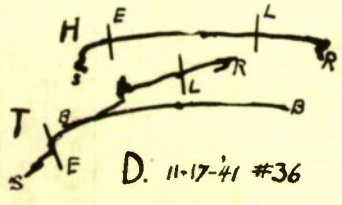
Subj-H: 12/2/41,#36,5P.M.12.2°C,78H,SW-4,NC27644
S2:00P.M.2:12E2:15 2:38 3:02 3:48 L4:01 R4:19
TC26.5 26.0 28.3(60min)28.3 23.0 29.5 29.5
H% 33 95 95 86, 95 100 100 100
Note: Plane landed at 2:52P.M. Instructor left ship. Landing and take-off's practiced, student solo'd. Ready for solo license.
Note: Indications caused by landings. Flight period longer than usual.

9.



Subj-D: 11/13/41,#36record"B",5P.M.8.3°C,55H,SW-9,NC27646
S12:52 E12:55 1:00 1:12 1:14 L1:27 L:33,1:37R1:44
TC25.2 25.7 26.5(12 min)26.5 29.5 29.5 32.4 34.5
H%33 86 91 100 91,100 91 86 95 86
Note: Plane landed 1:15, and took-off.

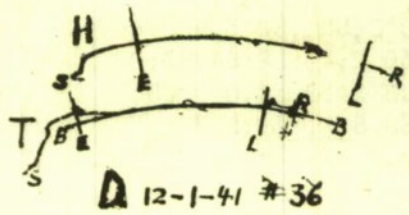
10.



Subj-D: 11/17/41,#36,5P.M.8.3°C,31H,W-5,NC27646
S12:37 12:44 E12:45 1:05 L1:18 1:20R1:30
TC23.0 23.9 28.4 29.5 29.5 32.3 35.2 26.4,37.0
H% 33 86 100 100 100 95, 86 91 86 91
Note: Landings and take-off's practiced during entire period.

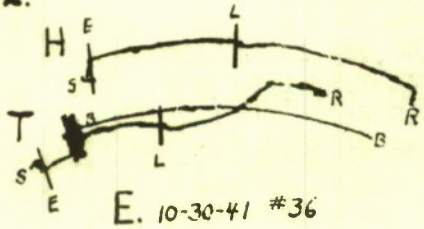
Chart 2
C.A.A.-N.R.C. Micro-Recorder Records 6-10

11



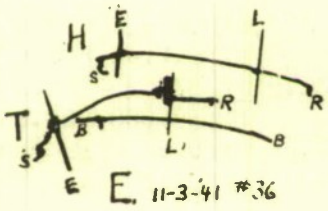
Subj-D:12/1/41,#36,5P.M.12.2°C,78H,SW-4,NC27646
S2:18 E 2:35 L3:25 R3:32
TC23.0,32.3,33.0 33.0 29.7 29.5 31.0 31.0
H% 33 95 95 100 100 86 86 91 91
Note:Flight period longer than usual for C.P.T. student, since he was allowed to solo, after plane landed and instructor left ship.

12.



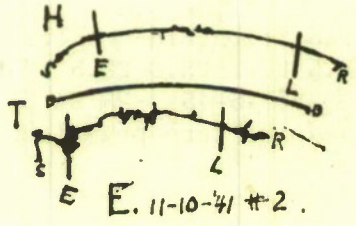
Subj-E: 10/30/41,#36,5P.M. 11.1°C,71H,W-4,NC27647
S1:36 E1:38 1:48 1:58 2.06 L2:10,2:16,2:41 R2:54
TC25.7 23.5 24.1 28.1 27.5 26.5 25.0 35.3 35.3
H% 33 77.5 82 (30 min) 82 64 86 77.5 64
Note: Practiced level flying.

13.



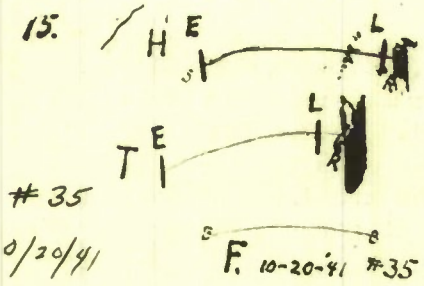
Subj-E: 11/3/41,#36,5P.M.14.0°C,53H,SW-3,NC27647
S1:32 E1:38 2:02 L2:10 R 2:22
TC22.0 27.6 35.2 24.5 24.5 24.7
H% 33 80 95 100 100 95 95 91 91
Note: Landing and take-off clearly shown by bubble like indications. Usual procedure.

14.



Subj-E: 11/10/41,#2,5P.M.7.7°C.,54H,NW-3,NC27646
S1:10 1:12 1:17 E1:20 1:30 1:36 1:48 1:58 L2:06 R2:18
TC22.2m39.7, 26.5 26.5 28.1 30.7 29.3 27.3,26.5 26.7
H%48, 85 88 88 94 94 100 100 97,94,88
Note: Ten minutes during flight when readings impossible. Landed and took-off twice during flight,1:44,2:00

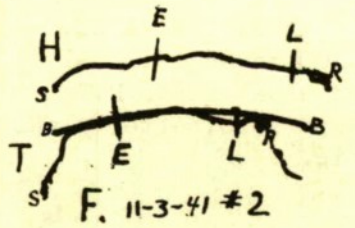
15.



Subj-F: 10/20/41,#35,5P.M.15.6°C,57H,SW-8,NC29590
Note: Recorder placed on student while seated in plane to begin flight.
E3:06P.M. 3:16 3:26 L3:41 343 R3:50
TC 21:0 25.0 25.5 25.5 26.1 26.1
H% 33 73 95 (25 min) 95 98 98
Note: Recorder placed on subject while seated in plane, plane ready for take-off. Practiced level flying.

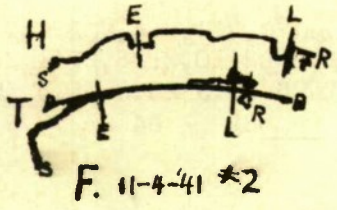
Chart 3
C.A.A.-N.R.C. Micro-Recorder Records 11-15

16.



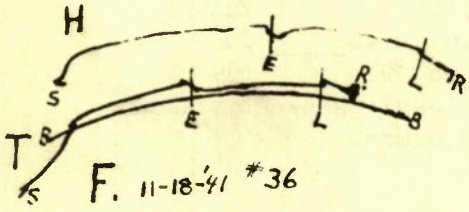
Subj-F: 11/3/41,#2,5P.M.14.0°C,52H,SW-3,NC27647
S1:56P.M.2:00 2:14 E2:20 2:36 2:40 L2:54 R3:00
TC20.7 27.8 35.1 35.6 35.8 34.8 34.0 35.4
H%48.5 88 69.5 82 91 69.5 69.5 79 79
Note: Practiced level flying.

17.



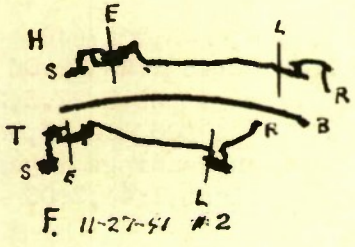
Subj-F: 11/4/41,#2,5P.M.13.3°C,44H,5-7,NC29590
S2:00P.M. 2:08,2:19 E2:21 2:46 2:56 L258 R3:02
TC22.7 33.0 35.7 35.5 35.5 36.6 36.9 36.9
H% 33 42 91 48 84 88 66 39 69 69

18.



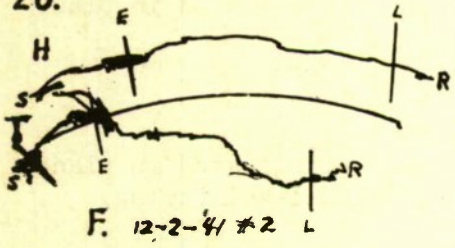
Subj-F: 11/18/41,#36,5P.M.14.0°C,61H,S-8,NC27646
S1:27 1:57 2:12 E2:16 L2:46 R2:54
TC23.8 31.8 33.1 31.0 31.8 32.3 33.1
H% 33 86 56 77 42 84 84,68 50.5
Note: Landings and take-off's practiced. Has seven hours of flying at this period.

19.



Subj-F: 11/27/41,#2,5P.M.,12.2°C,44H,SW-7,NC-27644
S2:09P.M. 2:13 2:17 E2:18 2:25 2:43 L2:57 R3:10
TC26.3 33.5 30.7 30.7 32.5 26.3 25.0 22.5 33.5
H% 33 72.5 33 33 79 33 45-45 75 94 33
Note: 7-20's, steep turns and spins were practiced during period.

20.



Subj-F: 12/2/41,#2,5P.M,12.2°C,78H,SW-4,NC27646
S2:42 3:00 E3:06 3:16 4:02 L4:10 R4:17
TC35.0 36.5 33 30.7 14.4 17.8 20.6
H%54.5 79 48 79 85 69 79 69 79
Note: During period plane landed and instructor left the ship, student solo'd remainder of period. Ready for solo license.

Chart 4
C.A.A.-N.R.C. Micro-Recorder Records 16-20

pre-flight and post-flight periods. Some students came just before the time for their scheduled lessons. Hence the recorder was attached for only a brief period before they went to the plane. Others came early, or after they arrived their lessons were delayed, and longer tracings were procured. Similarly for the post-flight period; some students wanted to leave immediately, others stayed about for several minutes.

In Table 2 temperature results are presented for the first trials made on each of ten men, most of whom were CPT students. The columns beginning at the left represent: The subject, designated by letter, the number of the Micro-Recorder that was used, the weather temperature, and the total number of minutes for the entire record. The remainder of the table is divided into three portions for the three periods. Under "pre-flight period" there is a column giving the duration in minutes after the recorder was mounted on the subject's hand before he went to the plane. This interval varied from 2 to 50 minutes. The next column, headed S shows the temperature reading at the time the recorder was mounted on the subject's hand. The next two columns are headed "representative temperature," one is headed "early," the other "later." The times which corresponded to these temperatures were of course recorded in our notes, but for sake of simplicity they have been omitted from the tables. The last column under "pre-flight period" represents the highest temperature found in this period. The same arrangement of columns is followed for the "flight period," and in general for the "post-flight period." In the later division there is only one column for "representative temperature." The same scheme of tabulating the data is followed in Table 3, which gives humidity results on these ten men during first trials. Tables 2 and 3 should be considered together.

Viewing the temperature results in Table 2 as a whole it is evident that some men's hands were pretty cold and some were pretty warm. The range before flight was from 15.0° for Subject C to 33.5° C. for Subject B, both records being made with the same recorder. If the comparisons are limited to the column which gives the "highest" value, the range is 20.7° to 35.5° C. Four of the men are 30° or higher, six are below 30° but higher than 20°. In the flight period the temperature range is still greater, from 14.5° to 35.0°, subject B again showing the highest value, while Subject I is low here as well as in the post-flight period. Subject I had his lesson on a day when the weather temperature was the lowest for the group (5.0° C.) This undoubtedly has something to do with his temperature picture. In these preliminary records it was not possible to equate the records for the weather temperature. The averages for Table 2 show a rather smooth trend. In the pre-flight period after the recorders were put on, there was a gradual elevation indicated by the values 26.4, 26.4, 26.8, with 27.8 as the average for the highest point. At leaving the waiting room and entering the plane there was a decline, on the average 0.8 degrees. This was followed by a further slight descent to 25.7. Later in the flight there was an increase to an average of 27.8, which happens to be identical with the average for the highest point before flight. At landing, the temperature remained at the level shown in the later part of the flight. There was a slight decline corresponding to the pilot's leaving the plane and going to the waiting room. Averages for the highest points show an upward trend from pre-flight to post-flight, 27.8, 29.0, and 30.0° C.

TABLE 2

CPT STUDENTS FIRST TRIALS - TEMPERATURE RESULTS

Subject	Recorder No.	Weather Temp. C°	Total Record Time, Min.	Pre-Flight Period					Flight Period					Post-Flight Period			
				Duration Min.	"S" C°	Rep. temp. Early C°	Rep. temp. Later C°	Highest C°	Duration Min.	"E" C°	Rep. temp. Early C°	Rep. temp. Later C°	Highest C°	Duration Min.	"L" C°	Rep. C°	Highest C°
N	3	15.6	73	50	28.0	26.0	30.0	30.0	20	28.0	28.0	28.0	28.0	3	28.0	28.0	28.0
G	36	15.6	47	10	25.7	25.7	25.7	25.7	35	25.7	25.2	29.5	32.4	2	32.4	32.4	32.4
M	3	18.3	98	45	27.0	28.0	29.2	31.7	35	29.2	30.5	31.7	31.7	18	31.7	30.5	31.7
H	36	18.3	47	5	28.6	27.8	27.8	28.6	39	28.0	31.0	34.0	34.0	3	32.3	31.0	32.3
B	2	20.0	58	18	32.6	32.6	33.5	33.5	35	32.0	33.5	35.0	35.0	5	35.0	34.5	35.0
C	2	11.1	39	2	15.0	20.7	20.7	20.7	35	20.7	23.6	29.2	30.7	2	30.7	26.5	30.7
E	36	11.1	78	2	25.7	23.5	23.5	25.7	32	23.5	24.1	27.5	28.1	44	26.5	25.0	35.3
K	2	6.7	107	17	32.0	31.0	29.2	32.0	60	29.2	23.5	25.0	29.2	30	18.7	20.7	22.7
I	2	5.0	68	5	23.5	21.7	21.7	23.5	33	17.9	15.0	14.5	15.0	30	14.5	13.2	22.2
A	36	12.2	98	17	26.0	27.0	26.3	27.0	67	25.7	22.5	23.5	25.7	14	25.7	28.3	29.5
Averages					26.4	26.4	26.8	27.8		26.0	25.7	27.8	29.0		27.6	27.0	30.0

TABLE 3

CPT STUDENTS FIRST TRIALS - HUMIDITY RESULTS

				Pre-Flight Period					Flight Period					Post-Flight Period			
Subject	Recorder No.	Weather Humidity %	Total Record Time Min.	Duration Min.	"S" H%	Rep. Hum. Early H%	Later H%	Highest H%	Duration Min.	"E" H%	Rep. Hum. Early H%	Later H%	Highest H%	Duration Min.	"L" H%	Rep. H%	Highest H%
N	3	57	73	50	40	92.5	100	100	20	88.5	88.5	88.5	88.5	3	88.5	88.5	88.5
G	36	57	47	10	33	82	77.5	82	35	82	86	86	86	2	86	86	86
M	3	75	98	45	70	88.5	88.5	88.5	35	88.5	70	70	88.5	18	88.5	96	96
H	36	75	47	5	42	64.5	64.5	64.5	39	86	82	82	86	3	86	68	86
B	2	45	58	18	79	91	79	91	35	79	91	85	91	5	72	79	79
C	2	51	39	2	48.5	61	61	61	35	61	97	94	97	2	94	73	94
R	36	71	78	2	33	33	77.5	77.5	32	77.5	82	82	82	44	64	77.5	86
K	2	58	107	17	33	97	97	97	60	97	97	94	97	30	94	88	97
I	2	70	68	5	36	33	33	36	33	33	48.5	39	58	30	33	77	77
A	36	44	98	17	33	95	86	95	67	95	91	100	100	14	100	100	100
Averages					44.8	73.8	76.4	79.2		78.7	83.3	82.0	87.4		80.6	83.2	88.9

The humidity results as given in Table 3 also show fairly wide individual differences. In the pre-flight period only one subject touched 100%, but seven were 75% or above (see column headed "later"). Subject I is again low man. In the flight period and also in the post-flight period, there was only one case that reached 100%. In terms of averages, the flight period as a whole seems to be a full 5% above the general level for the later portion of the pre-flight period. With the exception of the drop that occurred at the time of landing, the post-flight period continues at the same level as shown for the flight period. Examination of Tables 2 and 3 together reveals that the flight period is not sharply marked off from the pre-flight and post-flight periods. There is, however, some tendency for the humidity to rise during the early part of flight. The rise in humidity with flight is demonstrated with seven of the ten subjects. Six appear to demonstrate a rise in temperature.

The second trials for seven subjects are presented in Tables 4 and 5.[17] Table 4 shows a narrower range of individual differences than is found in Table 2. The averages indicate that the flight period taken as a whole is characterised by higher temperatures than were recorded during the pre-flight period. The post-flight period continues at approximately the same level as found for the flight period. There is a progressive rise in the averages for "highest" values in the three periods. The humidity results (Table 5) are in general similar to those for temperature. They show a narrower range of individual differences than found in Table 3, and in terms of averages, a slightly higher percentage of humidity for the flight period as contrasted with the pre-flight period, with a slight tendency for a decline in the post-flight period.

Repeated trials were taken on some subjects at different points in the training. Tables 6 and 7 give temperature and humidity results for two of these subjects, M and H. It is evident that subject M, the man who had been unable to get his private license following C.P.T. training, follows the pattern of showing higher temperatures in flight than in pre-flight. In post-flight his temperatures declined in three out of four trials (Table 6). The humidity results for subject M (Table 7) are higher in the flight period than in the pre-flight interval and in the post-flight period are still higher than in the flight period. Subject H reverses this picture to some extent. For temperature, the flight period is higher than the pre-flight period, but not as high in general as the post-flight period. While for humidity (Table 7) the flight period is the highest, the post-flight period somewhat lower, and the pre-flight period still lower.

Similar results for two other Subjects E and B are given in Tables 8 and 9, respectively. The general temperature level for both subjects is higher in the flight period than in the pre-flight period, but for Subject E the post-flight period shows a decline, while for Subject B the post-flight period shows an increase. For humidity Subject E shows a fairly marked increase in

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[17] These are not in all cases the same subjects as represented in Tables 2 and 3 because unfortunately Recorder No. 17 (used in both first and second trials on some subjects) had its adjustment changed in some manner after calibration, and the humidity records with it could not be used.

TABLE 4

CPT STUDENTS SECOND TRIALS -TEMPERATURE RESULTS

Subject	Recorder No.	Weather Temp. C°	Total Record Time Min.	Pre-Flight Period					Flight Period					Post-Flight Period			
				Duration Min.	"S" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"E" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"L" C°	Rep. C°	Highest C°
H	36	6.7	84	8	28.4	22.3	22.3	22.3	31	22.3	23.9	24.4	24.4	45	23.1	35.2	35.2
M	3	5.6	150	94	25.0	27.0	22.3	28.5	55	22.3	25.5	28.0	30.5	1	28.0	28.0	28.0
B	36	15.6	57	16	25.7	26.0	26.5	27.8	37	28.0	27.6	28.0	28.0	4	28.0	28.4	28.6
L	2	5.6	93	26	28.0	29.3	30.3	31.3	33	31.3	28.0	25.6	29.3	34	25.6	21.7	27.5
E	36	14.0	50	6	22.0	27.6	27.6	27.6	32	27.6	31.2	35.2	35.2	12	30.1	24.5	24.7
D	36	8.3	52	3	25.2	25.7	25.7	25.7	32	25.7	26.5	26.5	29.5	17	29.5	30.0	34.5
J	36	11.1	60	23	29.5	31.0	26.3	33.0	34	26.3	25.5	25.7	25.7	3	25.7	25.7	25.7
Averages					26.3	27.0	25.9	28.0		26.2	26.9	27.6	28.9		27.1	27.6	29.2

TABLE 5

CPT STUDENTS SECOND TRIALS - HUMIDITY RESULTS

Subject	Recorder No.	Weather Hum. %	Total Record Time Min.	Pre-Flight Period					Flight Period					Post-Flight Period			
				Duration Min.	"S" H%	Rep. Hum. Early H%	Rep. Hum. Later H%	Highest H%	Duration Min.	"E" H%	Rep. Hum. Early H%	Rep. Hum. Later H%	Highest H%	Duration Min.	"L" H%	Rep. H%	Highest H%
H	36	58	84	8	33	86	86	86	31	86	92	86	92	45	82	91	91
M	3	49	150	94	33	92.5	86	100	55	86	86	96	100	1	86	86	86
B	36	78	57	16	55	55	86	86	37	86	77.5	64.0	77.5	4	77.5	33	77.5
L	2	49	93	26	33	85	94	94	33	94	91	94	94	34	94	94	94
E	36	53	50	6	33	80	95	95	32	95	100	95	100	12	95	91	91
D	36	55	52	3	33	86	86	86	32	86	81	91	100	17	91	86	95
J	36	51	60	23	42	77.5	82	82	34	77.5	91	95	95	3	91	91	91
Averages					37.4	80.3	88.0	90.0		87.2	88.4	88.7	94.1		88.1	82.0	89.3

TABLE 6

REPEATED TRIALS WITH INDIVIDUAL SUBJECTS - TEMPERATURE RESULTS

Subject - M

Recorder No.	Weather Temp. C°	Total Record Time Min.	Pre-Flight Period					Flight Period					Post-Flight Period			
			Duration Min.	"S" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"E" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"L" C°	Rep. C°	Highest C°
3	18.3	98	45	27.0	28.0	29.2	31.7	35	29.2	30.5	31.7	31.7	18	31.7	30.5	31.7
3	5.6	150	94	25.0	27.0	22.3	28.5	55	22.3	25.5	28.0	30.5	1	28.0	28.0	28.0
2	11.1	61	6	30.7	30.7	30.7	30.7	42	30.7	29.2	32.0	32.0	13	32.0	30.1	31.5
36	13.3	72	39	27.0	26.0	25.7	26.0	10	25.4	26.3	26.3	26.3	23	26.3	27.0	28.0
Averages				27.4	27.9	27.0	29.2		26.9	27.9	29.5	30.1		29.5	28.9	29.8

Subject - H

36	18.3	47	5	28.6	27.8	27.8	28.6	39	28.0	31.0	34.0	34.0	3	32.3	31.0	32.3
36	6.7	84	8	28.4	22.3	22.3	22.3	31	22.3	23.9	24.4	24.4	45	23.1	35.2	35.2
36	11.1	106	50	25.7	28.5	33.5	34.4	30	30.2	31.3	32.9	34.4	26	34.4	34.0	35.2
36	12.2	139	15	26.5	25.5	26.0	26.0	106	26.0	28.3	28.5	29.5	18	29.0	29.5	30.0
Averages				27.3	26.0	27.4	27.8		26.6	28.6	30.0	30.6		29.7	32.4	34.2

TABLE 7

REPEATED TRIALS WITH INDIVIDUAL SUBJECTS - HUMIDITY RESULTS

Subject - M

Recorder No.	Weather Hum. %	Total Record Time Min.	Pre-Flight Period					Flight Period					Post-Flight Period			
			Duration Min.	"S" H%	Rep. Hum. Early H%	Rep. Hum. Later H%	Highest H%	Duration Min.	"E" H%	Rep. Hum. Early H%	Rep. Hum. Later H%	Highest H%	Duration Min.	"L" H%	Rep. H%	Highest H%
3	75	98	45	70	88.5	88.5	88.5	35	88.5	70	70	88.5	18	88.5	96	96
3	49	150	94	33	92.5	86	100	55	86	86	96	100	1	86	86	86
2	71	61	6	48.5	48.5	48.5	48.5	42	48.5	85	63	94	13	94	82	94
36	44	72	39	33	86	86	86	10	86	82	82	82	23	82	91	91
Averages				46.0	79.0	77.1	81.0		77.0	81.0	77.8	91.0		87.5	88.8	92.0

Subject - H

36	75	47	5	42	64.5	64.5	64.5	39	86	82	82	86	3	86	68	86
36	58	84	8	33	86	86	86	31	86	92	86	92	45	82	91	91
36	64	106	50	33	86	86	91	30	86	86	86	86	26	86	82	91
36	78	139	15	33	88	95	95	106	95	86	95	100	18	100	95	100
Averages				35.2	81.0	83.0	84.2		88.2	86.5	87.3	91.0		88.5	84.0	92.0

TABLE 8

REPEATED TRIALS WITH INDIVIDUAL SUBJECTS - TEMPERATURE RESULTS

Subject - E

Recorder No.	Weather Temp. C°	Total Record Time Min.	Pre-Flight Period					Flight Period					Post-Flight Period				
			Duration Min.	"S" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"E" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"L" C°	Rep. C°	Highest C°	
36	11.1	78	2	25.7	23.5	23.5	25.7	32	23.5	24.1	27.5	28.1	44	26.5	25.0	35.3	
36	14.0	50	6	22.0	27.6	27.6	27.6	32	27.6	31.2	35.2	35.2	12	30.1	24.5	24.7	
2	7.7	68	10	22.2	30.7	26.5	30.7	46	28.1	30.7	27.3	30.7	12	27.3	26.5	26.5	
Averages				23.3	27.3	25.9	28.0		26.4	28.7	30.0	31.3		27.9	25.3	28.8	

Subject - D

36	8.3	52	3	25.2	25.7	25.7	25.7	32	25.7	26.5	26.5	29.5	17	29.5	30.0	34.5	
36	8.3	53	8	23.0	24.4	23.9	24.4	33	28.4	29.7	34.4	35.2	12	35.2	37.0	37.0	
36	3.0	74	17	23.0	32.3	33.0	33.0	50	33.0	29.7	29.7	29.7	7	29.7	31.0	31.0	
Averages				23.7	27.5	27.5	27.7		29.1	28.6	30.2	31.5		31.5	32.7	34.2	

TABLE 9

REPEATED TRIALS WITH INDIVIDUAL SUBJECTS - HUMIDITY RESULTS

Subject - E

Recorder No.	Weather Hum. %	Total Record Time Min.	Pre-Flight Period					Flight Period					Post-Flight Period				
			Duration Min.	"S" H%	Rep. Hum. Early H%	Rep. Hum. Later H%	Highest H%	Duration Min.	"E" H%	Rep. Hum. Early H%	Rep. Hum. Later H%	Highest H%	Duration Min.	"L" H%	Rep. H%	Highest H%	
36	71	78	2	33	33	77.5	77.5	32	77.5	82	82	82	44	64	77.5	86	
36	53	50	6	33	80	95	95	32	95	100	95	100	12	95	91	95	
2	54	68	10	48.5	85	88	88	46	88	94.0	100	100	12	97	88	97	
Averages				38.3	66.0	86.8	86.8		86.8	92.0	92.3	94.0		85.3	85.5	93.0	

Subject - D

36	55	52	3	33	86	86	86	32	86	81	91	100	17	91	86	95	
36	51	53	8	33	86	100	100	33	100	100	95	100	12	91	86	91	
36	61	74	17	33	95	95	95	50	95	100	86	100	7	86	91	91	
Averages				33.0	89.0	94.0	94.0		94.0	94.0	91.0	100		89.3	87.7	92.3	

TABLE 10

RECORDS ON THREE STUDENTS DURING THIER FIRST SOLO FLIGHTS

Temperature

Subject	Recorder No.	Weather Temp. C°	Total Record Time Min.	Pre-Flight Period					Flight Period					Post-Flight Period				
				Duration Min.	"S" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"E" C°	Rep. Temp. Early C°	Rep. Temp. Later C°	Highest C°	Duration Min.	"L" C°	Rep. Temp. C°	Rep. Temp. C°	Highest C°
D	36	3	74	17	23.0	32.3	33.0	33.0	50	33.0	29.5	29.7	30.0	7	30.0	31.0		31.0
H	36	12.2	139	15	26.5	25.5	26.0	26.5	106	26.0	28.3	23.0	28.5	18	29.7	29.5		30.0
F	2	12.2	95	24	35.0	36.0	36.5	36.5	64	34.2	27.0	14.4	30.7	7	17.8	20.6		20.6
Averages					28.2	31.3	31.8	32.0		31.1	28.3	22.4	29.7		25.8	27.0		27.5

Humidity

	Hum.			Pre-Flight Period					Flight Period					Post-Flight Period				
D	36	61	74	17	33	95	95	95	50	95	100	86	100	7	91	91		91
H	36	78	139	15	33	95	95	95	106	95	91	95	100	18	100	100		100
F	2	78	95	24	54.5	79	63.5	79	64	48.5	79	82	85	7	79	79		79
Averages					40.2	89.7	84.5	89.7		79.5	90	88.0	95.0		90	90		90

the flight period over the pre-flight period, and in the post-flight period a decline to the level of the pre-flight period. B was about equally high in both the pre-flight and the flight periods, but in the post-flight period shows a decrease.

There were three subjects (Subjects B, H, and F) on whom records were secured during their first solo flights. On averaging these three records (Table 10), it was found that the pre-flight period was characterized in the two representative temperatures, by 31.3° and 31.8° C., the flight record by 28.3° and 22.4° C., the post-flight record by 27.0° C. While for humidity the pre-flight period showed 89.7% and 84.5%, the flight period 90.0% and 88.0% and the post-flight period, 90.0%. This would seem to indicate quite a definite fall in temperature during flight coupled with a rise in humidity. The high humidity and low temperature continued after the flights.[18]

Discussion and Conclusions

The appearance of tension and emotional stress in connection with the experience of learning to fly has been commonly reported by flight instructors and also not infrequently by those who are being taught. Instructors frequently tell students not to be so tense, to hold the stick lightly rather than to grip it, and to let the plane fly itself. Students in their lessons find it difficult to heed these instructions. Those interested in pilot selection and training have given considerable thought to the possibility of measuring tension and emotional stress and of identifying those students in whom these psychological phenomena are pronounced. It has seemed probable that measurements of this character might be based on circulatory and glandular responses. As one line of exploration in this direction, the C.A.A.-N.R.C. Micro-Recorder was designed and built. It is a small self-contained unit which registers graphically the temperature and moisture near the surface of the palm of one hand. It can be worn conveniently by the student pilot without interfering with his activities while flying. Having developed several such units and having standardized them, the next step was to try them out on a few students who were willing to cooperate, but were uninformed in reference to the exact objectives of the test. The trials were made in the Fall and early Winter when the weather temperatures were such as not to cause sweating independently of nervous tension.

The results which have been gotten so far with the use of the C.A.A.-N.R.C. Micro-Recorder must be regarded as preliminary and quite tentative. In certain respects they seem suggestive, but as a whole they are not very definitive in reference to the major problem which occasioned the development of this instrument. The data at hand seem to indicate that changes in the temperature and humidity close to the palm do occur during flight, in contrast to pre-flight and post-flight periods, and that these changes can be recorded objectively and conveniently. It appears that in most cases the

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[18] The pilots were extremely keyed up on these occasions and their records give evidence of this tension. (See Records 8, 11, and 20, Charts 2, 3, and 4, of the group illustrated.)

humidity tends to be higher during flight than preceding it, and in most instances the temperature also tends to be higher. This follows, because cooling of the skin by evaporation of the sweat cannot take place as normally for exposed skin since the recorder and its mounting tend to interfere with the normal rate of evaporation.

It seems probable that the humidity results are a better indication of the emotional condition of the subject than are the temperature tracings. The latter are more influenced by the environment. In the experiments presented in this report the design was not appropriate for dealing with the factor of environmental temperature.

A test of this character necessarily involves a number of variables, most of them difficult or impossible of complete control. The weather is one such group of variables. Records of this type depend upon the physical and mental condition of the subject; on his confidence in, and rapport with the instructor; on the student's stage of progress in his training course; on what kind of maneuvers he is practicing; on his confidence or lack of confidence for doing what is expected of him; and on the occurrence of mistakes, accidents, or hazards. Each flight experience has its own individuality, and can only be approximated in attempts to repeat it.

The C.A.A.-N.R.C. Micro-Recorder appears to possess possible usefulness for studying pilots. Like other measures, it will yield only meager results unless used in a very systematic manner. The experimental design should include a behavior record that can be compared or correlated against the objective tracings. If different students are to be compared, instructors' ratings are needed, not only for the flight as a whole, but designating the condition of the student during different parts of the flight and during the execution of different maneuvers. When one student is compared against himself the experimental design would include attempts at repeating the same standard flight under similar conditions, and different types of maneuvers under fairly similar conditions.